Transformation: a report

Stephen Whitmarsh[1,2]

[1]*Institute of Brain and Spinal Cord (ICM), Pitié-Salpêtrière Hospital, Paris, France*
[2]*1+1=3*

June 2019

1 Introduction

"The growth of musical art in any age is determined by the technological progress which parallels it. (...) If we admit that the creative imagination of the composer may form musical ideas which, under the specific conditions of a given epoch, cannot be translated into sounds, we acknowledge a great dependence of the artist upon the technical position of his era, for music attains reality only through the process of sound." (Schillinger, 1931)

2 Thursday May 30th: R1 Reaktorhallen

We began our events on the evening of May 30th at the decomissioned nuclear reactor hall R1, 25 memters under the centre of Stockholm. I presented a basic introduction, starting from Hans Berger's discovery of human EEG and alpha activity (Berger, 1931), to the first sonification for scientific purposes (Adrian & Matthews, 1934), the first EEG-sonification in an artistic performance (Lucier, 1982), to our own open-source initiative developing open-source software (Oostenveld & Whitmarsh, 2015) and its use for real-time EEG analysis in artistic performances (Whitmarsh, Huttner, Huhta, Takahashi, & Oostenveld, 2016). We ended with the ubiquitous presence of feedback systems in nature, and between (human) beings in particular. Consider, for example, a mother suckling a baby: The suckling of a baby stimulates the nerves in the nipple, which result in the hypothalamus increasing the release of oxytocin and prolactin in the pituitary gland, leading to an increased lactation which in turn increases the suckling behavior of the baby, until the baby is satiated. Looking at feedback in brain-computer(-music)-interfaces in this way deemphasizes the digital and 'cold' aspect of such as system, and emphasizes the emergence of new cybernetic systems in which causality and control are circular and emergent, rather than linear and individual. This emphasis on emergence rather than on

Figure 1: Event poster by Samon Takahashi

control has evolved from our practice over the years. We came to realize that the attempt to consciously control music with EEG is, in fact, not the most interesting or satisfying aspect for the performer, and in fact precludes full immersion into a brain-music connection. We found that a more receptive and passive attitude often resulted in a more profoundly relaxing and psychedelic[1] experience. Secondly, measurements of EEG are always noisy and the relationship between EEG signals and mental functions at best 'loose' as well. Since perfect fidelity and perfect conscious control of EEG are impossible, therefor, an unavoidable unpredictability is brought into the system, which can be either ignored or used constructively. It is quite uncommon to see these issues explored in an honest and creative way. David Rosenboom, however, has explored unpredictability in music and the ramifications of brain-music feedback loops over the course of his career. The presentation finished, therefor, with a quote from his *Biofeedback and the arts, results of early experiments* (Rosenboom, 1976): "*[Biofeedback in art] should be seen as the circulation of information about functions within an organism in ever widening feedback loops involving the consciousness of that organism, to serve its creative extension, beyond the structure of its own prior self-definition, in the natural meta-evolution of its self-organization dynamics*".

It was then time for a series of performances by Atau Tanaka: *Le Loup*, *Lifting* and *Myogram*. Atau first took a couple of minutes to introduce the two multichannel EMG arm bracelets, which he would be using to control different aspects of sound. I was impressed how clearly he was able to explain the techniques behind what would be happening, in only a couple of minutes and without the use of a single visualization (in contrast with my scientist's PowerPoint presentation). However, it did not prepare for the magnitude of the performance. Besides the responsiveness of his system, his muscles and movements mapped also perfectly to the three-dimensional sound diffusion, amplifying his body into a musical instrument as large as the room. His fingers and arms moved sometimes small and jazzy, sometimes expansive and dramatic, as a conductor of an orchestra of invisible sonic ghosts. I was able to discern the use of EMG envelopes, as well as the sonification of 'raw' muscle activity, the latter sounding like electricity which he conjured up into almost tangible shapes around his body, throwing them around the audience in loud sweeps that made the rigging of the reactor hall charm with resonating overtones. It was an arresting, visceral experience.

It was then time for a break and a visit to the bar which Per set up, in wonderful kitschy colors contrasting with the grayness of the reactor hall. During dinner, only an hour before, we discussed how much we should charge for a beer. Fifteen minutes later, Robert had Per Huttner (who was serving as the bar man) wear a chest belt, and programmed the EEGsynth in such a way that a screen on the bar displayed the price of beer depended on his heart-rate. It was quirky and fun, and the audience accepted the fluctuating prices with enthusiasm.

Figure 2: David Rosenboom performing with piano, violin and two EEG participants at R1

The last performance of the day was by David Rosenboom, who started and ended with two solo pieces on piano (including resonators and electronic synthesis), bookending his third and newest realization of Portable Gold and Philosophers Stones, first created in 1972 (Rosenboom, 1975), just then re-released with the suffix: Deviant Resonances (Rosenboom, 2019). Where Atau's performance still provided a way to see the relationship between the biological signal (EMG) and its sonification by his use of gestural movements, we now dealt with the sonification of (EEG) brain activity provided by two audience members silently sitting and listening at the center of the stage. David himself played the piano and his violin that was connected to a modular synthesizer using a 6 band fixed filter, envelope followers, VCAs and Make Noise's Morphagene tape loop module. EEG-based performances can easily become be very static due to the immobility of whom the EEG is recorded. David's performance,

[1] As in "Mind manifesting" from the English psyche + Greek dēlos 'clear, manifest' + -ic.

however, moved wonderfully between his dynamic and energetic playing of his violin and the two absorbed active imaginative listener-performers (Rosenboom, 2014), in front of a slowly rotating video projection. The whole was transporting and absorbing. I tried to to pick apart the clusters of sound that swelled through the space, as David had introduced his piece in some detail and provided us some clues as what to listen for. Firstly, by responding to *changes* in the amplitude of alpha, musical events were triggered by changes in the attentional state of the participants. Furthermore, when two participants showed shifts of attention *at the same time* - e.g. in response to surprising sound in the music or the environment - resonating bells were heard. Afterwards, a question from the audience had the participants share some of their experiences, who reported being very deeply absorbed, loosing connection with time and space during the performance. The audience reported feeling themselves involved in the piece as well; an effect perhaps of the way David invited everyone to use their active imagination while listening to the music.

3 Friday May 31st: Trädgården

The next day we moved to Trädgården, the largest club in Stockholm, where we installed ourselved in their 'Red Room'

In the first presentation, Severine Samson addressed the question of why music is important to study the brain, and vice-versa, what neuroscience can tell us about how the brain works. Neuroscience of music is, in fact, a very young field and, as is the onus of science, has started by first deconstructing the phenomenon, clarifying its terms and processes. While arguably still dealing with very basic questions of music appreciation and composition, some remarkable insights can already be glimpsed. While not necessary for survival or satisfaction of primary biological needs, music appreciation is shown to be universal across times and cultures. Neuroimaging shows that the pleasure music evokes involves the reward circuit in much the same way as less healthy activities, such as gambling and drug addiction. In fact, the brain processes music as a sequence of predictive and reward cues that occur over time, leading to a constant sense of anticipation. It is this creation of expectations through its temporal structure, that provides us with pleasure. Severine then talked about how music can also be used to study emotion, shared experiences, memory, synchronized movement, and many other functions and behaviors for which, while topics in their own right, music can provide a natural paradigm for its manipulation and scientific study. A topic turned out to be particularly evocative was the universal response to physical characteristics of sound used in music, such as dissonance and harmony. What Severine's research showed, was that the brain processes these 'proto-musical' stimuli very early on, within tens of milliseconds, after which higher-order brain regions interpret them and assign value and meaning to them. Like many other brain processes, the first responses of the brain represents the physical characteristics of the stimuli, while only later (but very quickly) our training, conditioning, attention and culture kicks in. Why dissonant stimuli seem to be universally regarded as negative by these early brain regions remains unknown, however. Art and science need each other if we want to truly get to the heart of it. For example, a methodological problem that researchers like Severine are struggling with, is the lack of musical stimuli that are novel and can span the emotional spectrum while remaining relatively similar in their physical characteristics. Currently, these stimuli are dominated by culture, such as the use of western film-music, or pieces of classical western music. Another animated converstion was triggered by her questions on how we should best understand improvisation. We discussed how improvisation and composition might represent a false distinction, a topic we will come back to later. Severine also voiced her enthousiasm in the promise of music-neurofeedback in learning and rehabilitation (the reward circuit!). If there was one thing that Severine was able to bring across, it was that all of us: the artist, the musician and the scientist, have unique and valuable knowledge to bring to the table when it comes to the (neuro)science of music, a topic which is by its very nature highly interdisciplinary.

Samon Takahasi then presented his ongoing work in the history of *brainwave music*[2]. It is a completist project in which he keeps uncovering artistic works that have either used or stimulated the use of EEG recordings in visual art, music and performance. In fact, by now a full chronology would have taken much more time than we could possibly program. Furthermore, there are many stories to tell. As came up in our conversations several times, there is never a single beginning or a 'first', that cannot be traced back to multiple pasts. Samon therefor gave a brief overview demonstrating the interwoven history of early experimental

[2]a term actually borrowed from the title of David Rosenboom's first EEG-based music record(Rosenboom, 1975)

art, music by science, and the emergence of the artistic project of showing and sonifying invisible realities of electromagnetism. A selection of wonderful images of known and lesser-known works accompanied his presentation, tracing history into the present moment, and bringing home the unique situation to discuss seminal moments in art history with those that were present there.

In the evening, the Trädgården started filling up with young club-goers, and it became time for our evening program. We started with a brainwave music performance by Jean-Louis Huhta, Per Huttner and Robert Oostenveld. Their piece 'an-atomic' had been performed and fine-tuned several times over the last year, and their experience showed. Robert introduced and shortly explained how he would record Per's EEG and used his alpha power to create control signals for both Jean-Louis' modular synthesizer as well as for a video projection. Per was seated with his back to the audience, facing an LED ring that responded to his alpha activity, using neurofeedback to help him setting in a receptive state of mental relaxation. Jean-Louis' music slowly faded in, and created an impressive diversity of sonic textures and moods that fit wonderfully well with the movie projection. Per's alpha activity subtly faded between several versions of his movie, which were slightly shifted in color or pace, creating an hypnotic responsive background to his meditative performance. Per's combination of images of foliage, abstract images and urban scenes created an poetic journey that merged very well with the sonic journey of Jean-Louis' EEG-controlled composition.

Figure 3: Robert Aiki Aubrey Lowe at Trädgården

The brainwave music set was followed by a melodic synthesizer and vocal performance by Sonja Tofik and Mar-Ilena, who provided some breath and space, opening up our minds again to the next intense performance.

It was then time for Robert Aiki Aubrey Lowe's performance, in which he played his modular synthesizer bathed in a video projection of stunning color schemes, geometric shapes and stroboscopic movements. His performance was arresting, melting his voice, contact microphones, skin conductance modules and visual art into a performance that was both theatrical and self-absorbed. Every manipulation of his modular synthesizer was purposeful and confident, expressing an organic connection between signals, circuits and himself. While the set was one of improvisation - he later told us that things were going another direction than he expected - he was in full control of both his mind and his music, drawing the rowdy audience in, with his mesmerizing performance.

The intensity could only go up from there, and was done so by Stockholm-based Kult Dopamin (Didrik Goldkuhl), playing his first gig with a relentless set of acid techno, after which the night continued into the small hours with a DJ-set by Mar-Ilena and Jean-Louis.

4 Morning of Saturday June 1st: Trädgården

We reconvened the next morning for a presentation by David. We expected perhaps too much from our audience, and we were only joined by a handful of visitors. This was good fortune for those present, as we were able to hold an intimate conversation, triggered by the topics David brought to bear. It would be too much to reiterate all that was discussed, so I will only mention some. David explained how he has developed his practice by considering 'intelligent' agents that interact through, or within, 'musical states'. By considering such circular causality between both minds and instruments (and bracketing the elusive concept of intelligence), and focussing on the common state in which those can communicate, a more inclusive understanding of generative co-evolving music and the musical processes can be gained. This perspective was shared by all musicians that were present. For example, Robert Aiki Aubrey Lowe explained how both in the brain and in the modular synthesizer, electrical signals are routed and exchanged in a way that boundaries between them can become transparent. Such an 'organic' and communicative relationship is

part of his musical personal practice, and was apparent in his powerful performance the previous evening. Similarly, in Atau Tanaka's practice, electrical signals from his brain are translated to his muscles, which in turn are transformed into sound - creating a circularity in which the instrument is imbued with an intelligence that for all intents and purposes has a mind (body?, music?) of its own. Triggered by a question of Severine Samson, we also discussed the concept of improvisation and composition in the light of electronic music. The musicians all agreed that this distinction only makes sense in the western classical tradition where compositions are created separately by composers to be played by performers. In other times, and cultures, such distinction falls apart. Composition-improvisation should perhaps be considered as the way an expert musician listens and responds with his/her full cultural history and personal training. Rather than considering composition and improvisation as separate processes, (neuro)science of music might therefor do well to leave such an artificial distinctions behind and rather explore the decision-making processes that musicians make at every step of their performance. We all understood that such an integrated perspective is a very complex one, however, especially since it has to involve the unique individual background and experience of the musician.

David also presented an historical overview of his work, starting with his early experiments and ending with his recent compositions of brainwave music Hobscotch, an opera that occurred in 24 limousines, and in which brain activity of visitors controlled singing responses to increasingly personal questions [3]. Several early performances by David were unknown to us, and it brought home how much David had not only explored brain activity in music, but how he has engaged the full spectrum of visual art and performance. As an example, one early installation involved a double mirror placed between two participants. Each participant's EEG was recorded, with alpha controlling the brightness of the light at the opposite site of the double mirror. Due to the effect of light on a double-sided mirror, depending on their attentional state participants were either looking at themselves (more light on their side), or at the other (more light at the other side). It is a beautiful and elegant piece that stimulates thinking on empathy and brain synchronization in a way that is still relevant, not just in art, but certainly for the neuroscience as well.

Although we had planned some time to have the audience members experience the EEGsynth themselves, we decided to continue the conversation and regroup later that day for the final series of performances.

5 Evening of Saturday June 1st: R1

Figure 4: Ludvig Elblaus & Gerhard Eckel at R1

The evening started by a brainwave music performance with Samon Takahasi on EEG, and me on modular synthesizer, using the EEGsynth to modulate the patches with Samon's alpha activity. The enormous reverberations of the reactor hall allowed a sparse use of sounds and percussion. I therefor used a combination of a Verbos complex oscillator, several filters, a flanger, low-pass gate, bucket brigade delay, and stereo tube overdrive, to create a drone with minimal percussion, and in which I could 'dial in' the modulation by Samon's alpha activity. Like always, the patch quickly became an improvisation, and sounds appeared unplanned and seemingly outside of my control, only to be nurtured once their source was found. I much enjoy those unexpected movements that occur when a 'sweet spot' is, and felt happy with the result.

Second was a performance by Ludvig Elblaus and Gerhard Eckel, who had installed four microphones throughout the hall and reactor core, requiring over two hundred meters of microphone cable. During their performance, Ludvig and Gerhard were standing behind two midi controllers, which were connected

[3] http://hopscotchopera.com/

to two resonating filter banks running on Super Collider[4]. They created and sculpted the sound using only two speakers and their reverberations and the sound source. Their installation was set on a stainless steel trolley, with just the half-open laptop and two controllers, while the sound moved around them as if they were weather-controllers conjuring up a storm, or a pair of ghostbusters exorcising an haunted house. People slowly moved around, climbed the balconies and explored the living sonic space that they created. Sounds and their complex echos moved through and around you, in and out of experience, dilating time and space, disorienting then calming once you allowed yourself to settle int its sonic bath.

It was then time for a longer break at the heart-beat bar, while we set up for an improvisational jam with David Roosenboom, Atau Tanaka, Ludvig Elblaus, Gerhard Eckel, Jean-Louis Huhta, Per Huttner, Samon Takahasi, and me. This time, Atau used our hardware[5] to connect to his patches build in MAX/MSP. David his own EEG recordings to control the musical patches he programmed in Reactor, and played his violin as well, while Ludvig and Gerhard used their installation to feed off the sounds we created. Jean-Louis and Per started, David followed, after which we took our turns and played with each other, creating a large collage of sounds, integrating three EE recordings, EMG recordings, using both software and modular synthesizers. At one point I saw and heard Atau move perfectly synchronous with a rhythm of high-pitched glissandi I was making with a resonating vactrol filter. For a little I was confused, not knowing whether it was Atau or me who were creating the sounds, trying to listen and watch while tracing my patch chords, until I could only come up with the conclusion that Atau was moving and playing himself synchronously with my fluttering notes, so precisely that I could not tell who came first and who followed. It was then clear how much Atau was in control of his body-instrument. The performance build up to a load crescendo, then build down until only sounds triggered by David's brain remained, then faded out. It was a blast, and if the reaction of the audience was anything to go by, quite a unique experience.

6 Sunday afternoon, June 2nd: EMS

Figure 5: The Buchla synthesizer at EMS

We closed *Transformation* at the Elektronmusik Studion (EMS) for a private meeting. We had the fortune to have David explain to us the history and design of the Buchla 300, of which EMS is one of the few owners of the few existing.

Discussing all our plans for the future in detail would be out of the scope of this report. However, we would like to share one perspective. We live in very different time today, compared to the early experiments in brain-based art and performances. On the one hand, the possibility of electronic sound synthesis has become available for anyone with a small budget to spend on consumer hardware synthesizers or virtual synthesizers. Programming and an understanding of electronics have become unnecessary. Similarly, EEG has moved from the laboratories into the real-world with the availability of cheap consumer systems which, while often making questionable claims and questionable recordings, do allow home experimentation. These technological changes stand in stark contrast with their use in art, which does not seem to have evolved that much. It would not (only) be a matter of friendly affectation to say that David Rosenboom has been carrying the torch, consistently exploring new ideas, both in theory and practice, going beyond what most of us have even

[4]https://supercollider.github.io/

[5]A Ganglion board from the OpenBCI project, fitted in a 3D printed housing designed by Robert Oostenveld

attempted. Two challenges might be responsible for this slow adoption of EEG in art. Firstly, while their use has become easier, understanding EEG, and to some degree basic neuroscience, is still required to make productive use of it. Secondly, the actual interfacing with EEG still requires programming against devices, if not of EEG analysis itself. In fact, most BC(M)I devices face similar challenges and similar solutions can be adopted. In other words, there is a need for *sharing* solutions for BCI, especially in the field of art, where artist might be less independent dealing with engineering problems. The EEGsynth offers such a solution, with a well-documented flexible architecture that can be easily patched for purpose of the artist, requiring only the editing of text-files, and a basic understanding of the command-line. Importantly, patches can be fully documented, saved and distributed for reproduction, offering examples and ideas for further exploration by others. By using Python as a programming language, and GitHub for version control, everyone is (at least in principle) able to read the code and contribute with additions and improvements. This is further simplified by using a modular architecture in which the BC(M)I loop is constructed of individual parts that can be adapted to one's own purpose, taken from an increasing collections of modules that deal with anything from interfacing with different EEG hardware and musical devices, to the analysis of muscle, EEG or heart-beat or eye-blinks, or dealing with the calibration issues and recording and playback of original data or it's analysis. We have been able to use the EEGsynth in a wide variety of performances over the last five years, and several independent projects have used the EEGsynth. In this way, the artist could spend his/her time developing the concept and experience of their performance, documenting the performance to the point that it could be re-enacted in the future. One related plan for the future is to create several re-enactments of seminal early EEG-based works as an ode those pioneers, and to guarantee that the ideas and lessons drawn from those early works are shared, developed further.

7 Acknowledgements

We organized the Transformation program to try to connect our efforts with the wider community of like-minded artists and scientists, hoping to see beyond the event-horizon of our own limitations, struggles and habits. We did not expect our dreams to be surpassed as well. It is one thing to imagine, another to experience firsthand the expertise and creative explorations that our guests shared with us. Our heartfelt gratitude goes out to David Rosenboom, Severine Samson, Atau Tanaka, Robert Aiki Aubrey Lowe, Ludvig Elblaus, Gerhard Eckel, Fabien Guillermont, Sachiko Hayashi, and everyone else who participated. We also owe each other a measure of gratitude, for getting so far, developing our own practice together, and realizing this event. Spending these last days together was invigorating, both personally as well as a collectively, and made us feel both humbled and proud.

Transformation was made possible thanks to support from Musikverket, Stockholm Stad, the Nordic Culture Fund, Kulturbryggan and the Swedish Arts Council.

References

Adrian, E. D., & Matthews, B. H. C. (1934). The Berger Rhythm: Potential Changes from the Occipital Lobes in Man. *Brain*, *57*(4), 355–385. doi: 10.1093/brain/57.4.355

Berger, H. (1931, December). Über das Elektrenkephalogramm des Menschen: Dritte Mitteilung. *Archiv für Psychiatrie und Nervenkrankheiten*, *94*(1), 16–60. doi: 10.1007/BF01835097

Lucier, A. (1982). *Music For Solo Performer.* Lovely Music Ltd.

Oostenveld, R., & Whitmarsh, S. (2015). *EEGsynth: Converting real-time EEG into sounds, music and visual effects.* Eegsynth. Retrieved 2019-06-09, from `https://github.com/eegsynth/eegsynth`

Rosenboom, D. (1975). *Brainwave Music.* A.R.C. Records.

Rosenboom, D. (Ed.). (1976). *Biofeedback and the arts, results of early experiments* (2d ed ed.). Vancouver, B.C: Aesthetic Research Centre of Canada.

Rosenboom, D. (2014, August). Active imaginative listening - a neuromusical critique. *Frontiers in Neuroscience*, *8*. doi: 10.3389/fnins.2014.00251

Rosenboom, D. (2019). *Brainwave Music (Rerelease).* Black Truffle.

Schillinger, J. (1931). Electricity, a Musical Liberator. *Modern Music*, *8*, 26–31.

Whitmarsh, S., Huttner, P., Huhta, J.-L., Takahashi, S., & Oostenveld, R. (2016). *Oneplusonesithree.org.*